emanates from the sun in the manner here assumed." It is not improbable that the great mass of radiant matter into which we suppose we look when observing the zodiacal light, is capable of diffusing enough sunlight to produce the luminosity of that phenomenon.—[C. A., jr.]

A POSSIBLE CONNECTION BETWEEN MAGNETIC AND METEOROLOGIC PHENOMENA.

By KRISTIAN BIRKELAND.

[Reprinted from Miss Jessie Muir's English text of "The Norwegian Aurora Polaris Expedition, 1902–1903." v. 1, 2d section. Christiania. 1913. p. 449–450.]

93. If the view we have maintained is correct, namely, that the magnetic storms are due to corpuscular rays that are drawn in in zones round the magnetic poles, where they pass directly down into the atmosphere of the earth, it is clear that these rays, especially in the upper strata of the atmosphere, must be assumed to produce a strong ionisation in the air. In our expedition of 1902–03, atmospheric-electrical measurements were made, which will be gone into later on; but it may be remarked here, that the result of these measurements showed that the "Zerstreuung" of the air at those stations averaged about twice as much as in Christiania, indicating that the air up there is considerably more ionised than in lower latitudes. In an expedition which I made in company with my assistant, Mr. Krogness, to Kaafiord at the time when Halley's comet crossed the sun's disc in May, 1910, I had an opportunity of studying this matter more closely.

Instead of, as before, making the measurements at places that are at no great height above sea-level, I on this occasion investigated it at my old aurora observatory on the top of Haldde Mountain, about 910 meters above the sea. Here there proved to be sometimes tremendous variations. On the 20th May, for instance, values were found that went up to about 500 times the normal. Unfortunately the attempt was interrupted in the middle of these measurements; but I had an opportunity of making insulation-tests twice at that time, which proved there was no perceptible leakage. If we can demonstrate this circumstance with certainty, we presumably have before us a phenomenon that is closely connected with the peculiar light-phenomena that Lemström discovered in 1882–3 on a mountain-top at Sodankylä.

There is no doubt that such strong ionisations will have a very great influence upon atmospheric conditions, especially upon the formation of clouds, and must thus be assumed to be a meteorological factor of no small importance, especially for the districts in the vicinity of the auroral zone. I am of the opinion that this is a very important connecting link between terrestrial-magnetic and meteorological phenomena. I have therefore recently submitted to the Norwegian State authorities, a suggestion that a permanent up-to-date magnetic-meteorological observatory be established upon the top of Haldde, for the purpose, if possible, of throwing light upon these interesting and meteorologically important matters.

There was another phenomenon, striking examples of which we had the opportunity of seeing on this expedition in May, 1910, namely, the formation of what may be called auroral clouds. In addition to the usual polar bands, which in a clear sky, could very often be observed in the form of several evenly luminous arcs, of which, however, *one* was especially conspicuous, exactly similar to parallel auroral arcs, we very frequently found formations of cirrus clouds, which exhibited the most perfect agreement with various auroral formations. Several times we had capital examples of the manner in which such clouds are formed, how drapery-formations appeared in a short time, exactly in the same manner as an auroral drapery. The first observer, who has called attention to this very interesting fact seems to be Adam Poulson [Paulsen].[1] As far as I know, no one has, however, studied this phenomenon in connection with simultaneous magnetic registrations at the same place. This we had the opportunity of doing, and the very interesting fact came out, that the formation of these clouds was always accompanied by simultaneous magnetic storms and earth-currents; and there thus appears to be no doubt that these are direct cloud-forming effects of the same rays that occur in the auroral phenomena. From this it seems, that these cirrus-clouds are directly formed by the corpuscular rays which we suppose to be the cause of magnetic storms and aurora. The first hypothesis that one naturally might form as to this phenomenon is, that the clouds are due to water-vapor brought to condensation by the ions formed by the impact of negative rays. It is, however, also a probability that some of the observed "auroral clouds" are not real clouds, but merely a very strong concentration of corpuscular rays, which in the case of darkness might appear luminous; in the daytime the concentration of corpuscles should have the effect of making the places where they occur less transparent, and able to diffuse light, and thus become visible. In such a way also possibly certain faint polar bands observed in the polar regions might be explained. According to circumstances these concentrations may disappear, or perhaps give rise to real clouds.

[1] Paulsen, Adam. Wolkenbildung durch das Nordlicht. (Aus einer Mittheilung an die k. dänische Akad. d. Wiss., 1895.) Meteor. Ztschr., Wien, 1895, 12.Jhrg. p. 161–169.

RADIOTRANSMISSION AND WEATHER.

By A. H. TAYLOR.

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In a previous paper on this subject[1] the writer submitted evidence which seemed to show that unusually good radiotransmission across long overland distances at night is preceded the day before by generally cloudy conditions prevailing in the region across which the nocturnal good transmission takes place.

The evidence presented in that paper has been greatly strengthened by subsequent observations. In particular it may be mentioned, that out of some 60 cases of good transmission studied since September 24, 1913, 44 have followed a generally cloudy condition over the area in case, while of the other 16, a majority have occurred during the shortest days of the year, when the hours of sunlight in the latitude of Grand Forks, N. Dak., are relatively few.

Before discussing the bearing of this evidence on the idea of the reflection and refraction[2] of electric waves by ionized layers of the earth's atmosphere, it will perhaps be well to examine some of the data collected at this station since September 24, 1913, for evidence of a somewhat different character.

In commenting upon the previous paper, the editor of the Electrical World suggested that the effects noted

[1] Electrical World, Aug. 30, 1913.
[2] Dr. Eccles, in The Electrician, Sept. 27, 1912, and Sept. 19, 1913.

might have been indirectly due to general cloudiness, inasmuch as this would usually bring about some rainfall and would therefore probably reduce the ground absorption which is thought to be much larger in overland than oversea transmission. Fortunately the weather during the fall of 1913, especially during the months of October and November, was of such a nature in this part of the continent as to make it possible to settle this important question. The height of the aerial at this station is but 85 feet, so that the nearest of the Great Lakes stations do not usually make themselves heard until after dark. Nevertheless, during a period of over a month in which no moisture whatever fell in northern Minnesota the stations at Port Arthur, *VBA*, and Duluth, *WDM*, were heard as early as 4:30 p. m. on several occasions. Subsequent comparison of weather reports showed that in each instance the intervening region had been very cloudy. In spite of the fact that during this period no rain fell, or even snow until about December 1, there was a great deal of cloudy weather over northern Minnesota, and hence especially close attention was given to the transmissivity from *VBA* and *WDM*. In 80 per cent of the cases of very good transmission from these stations to this one (*9YN*) the preceding day had been very cloudy in this region. The effect of moisture on ground absorption is here eliminated. I am therefore forced to conclude that the effect of alterations of earth absorption are entirely overshadowed by the larger favorable influence of preceding cloudiness. Incidentally these experiments showed that the normal day absorption on clear days in this region is very large. This is supported by the fact that our own signals sent on a 500 meters wave with 7-amperes aerial current were but fairly received just before dusk in Minneapolis at the North Central High School with a 100-foot aerial, whereas less than an hour later they were repeatedly picked up by Mr. Keith Russell on a 70-foot aerial in Toronto. The first distance is 300 and the last 1,000 miles.

It has occurred to the writer to analyze data at hand for the possible influence of barometric pressure on transmission. The weather maps corresponding to the days preceding the evenings of observation were examined and 24 were found which indicated that rather low barometer readings had prevailed in or near the areas across which transmission had been studied. Of these only two were found to correspond with records of bad transmission, while the others all corresponded to records of good transmission. Inasmuch as the weather maps do not arrive here until the day after the transmission records are made, it is not possible for the observer to be prejudiced. Conclusions as to good or bad transmission were based on observations on Sayville, N. Y., call *WSL;* Arlington, Va., call *NAA;* Key West, *NAR* (1,800 m.); Wellfleet, Mass., *WCC;* San Diego, *NPL;* and the Lakes stations at Milwaukee, *WME;* Port Arthur, *VBA;* Duluth, *WDM;* Sault Ste. Marie, *VBB*. For reasons not at once apparent many stations on the Gulf of Mexico or in the Mississippi Valley are received here with extraordinary clearness. A good many observations were made on signals from battleships in the Gulf and upon Galveston, *WGV;* New Orleans, *WHK;* Fort Sam Houston, *WUJ;* Michigan University, *8XA;* Fort Leavenworth, *WUV*, and others. From the west coast, observations were also made upon Mare Island, *NPH;* Point Arguello, *NPK;* and occasionally upon Victoria, *VAK*. A great many other stations might be mentioned as being heard here when transmission was unusually good. A good many vessels were reported at this station, but it was not often possible to locate them very definitely. Finally, shunted telephone readings have been made on our own signals at Memphis, Tenn., by Brother John Berchmanns, of Christian Brothers College; at St. Louis, by Mr. A. S. Blattermann at Washington University; at Boulder, Colo., by Mr. Strock; and by Mr. H. S. Sheppard at Michigan University, in connection with certain tests to be reported on jointly in a future paper. Several amateurs at points from 600 to 1,100 miles distant have been kind enough to make written reports on the relative strength of our signals, among these Mr. Stockman at Denver, Colo., and Mr. Miller at Bushnell, Ill.

In reference to the influence of barometric pressure it must be noted that areas of low barometer are always more or less cloudy. In order to settle this point it is necessary to consider the cases where the barometer readings were generally rather high over the area studied. Of 18 cases which could be put in this class, 11 showed good transmission and 7 poor. But of these 11 cases of good transmission 4 were reported from the valley of the Mississippi, which the author has reason to believe permits phenomenally good transmission, and 6 were over generally cloudy areas. Of the 7 cases of bad transmission associated with rather high barometer, 5 were over very cloudy areas. The writer does not consider this evidence conclusive, but it might mean that high barometer is unfavorable to transmission. Clear-cut cases for long distances are not easy to find for either the high or the low barometer classes.

On the whole it seems as if the presence of clouds is the controlling factor, modified somewhat perhaps by barometric conditions. Bearing this in mind, it seemed worth while to attempt to find out whether cloudiness would be most beneficial at the sender or at the receiver. Accordingly the evenings of observation were divided as follows:

Weather conditions.	Transmission.	
	Good.	Bad.
1. Senders and receiver both in cloudy area	19	4
2. Senders and receiver both in clear area	7	6
3. Senders, cloudy; receiver, clear	14	3
4. Senders, clear; receiver, cloudy	8	7

From this analysis it seems that few cases of good transmission are reported when both stations have been in the clear area preceding the night of observation and about the same indifferent result is seen when the sender only has been in the clear. On the other hand, when the sender but not the receiver has been in the cloudy, the ratio of good to bad transmissions is about the same as when the cloudiness has been quite general. This ratio is 5 : 1 in favor of good transmission. Cloudiness in that portion of the area of transmission near the sender is evidently of the most importance in favoring transmission. This should have an important influence on the formation of any theory which will take account of the variations of nocturnal transmission as a function of the weather of the preceding day.

It seems to the writer that the most serious attempt to correlate fact and theory in long-distance transmission problems has been made by Dr. Eccles in the two papers previously mentioned. As he points out, the hypothesis of an upper layer of ionized air was suggested by Heaviside in 1900, and the idea of the production of such ionization by bombardment of cosmic dust has been advanced by Dr. W. J. Humphreys[3] to account for the fact that

[3] W. J. Humphreys, Astrophysical Journal, May, 1912.

according to the researches of Newcomb, Yntema, Campbell, and Abbot, there is received from the sky a total amount of light which exceeds the total light from the stars. Dr. Eccles seems to prefer, however, the hypothesis of Prof. Schuster [4] put forward to justify his theory of the diurnal variations of terrestrial magnetism. This would mean a gradual increase in ionization and hence in conductivity with the height, but on the whole a degree of ionization which would create a very great absorption. He points out that a very much smaller degree of ionization would suffice to explain some of the phenomena of long-distance radio transmission.

If the equations of the electromagnetic wave in free space be modified by the addition of a term representing the ionic convection current in the path of the wave, there results an expression for the wave velocity which exceeds that of light in free space. A better way of stating this is perhaps to say that the refractive index of ionized air would be less than unity, just as in the case of thin films of some metals whose refractive indices may be much less than unity for light rays. The effect of a refractive index diminishing with increasing altitude would be to tend to bend the waves back to earth, thus following more or less its curvature.

Dr. Eccles offers the very plausible suggestion in regard to the well-known facts of nocturnal long transmission, that the middle portion of the atmosphere is at night mainly un-ionized on account of the absence of sunlight, but that partial refractions occur at the very high permanently ionized layer. This reflection would not take place during the day, as there would be no very sharp transition from ionized to un-ionized atmosphere. His calculations on the amount of bending of long waves during the daytime show that a distribution of ionization is possible such that these waves, at certain critical altitudes (ranging from 40 kilometers for a 2,000-meter wave to 100 kilometers for a 200-meter wave) would suffer a refraction so abrupt as to be equivalent to a reflection, thus accounting for the possibility of long-distance transmission being better in the daytime with long waves than at night. This has been occasionally reported by Marconi of trans-Atlantic transmission. The writer has taken many observations on the 1,800-meter wave of Key West, on Arlington at 2,500 meters, and on Sayville at 2,800 meters, but on three occasions only, in the month of December, were any of them heard in the daytime at this station. The exception was Arlington, distant about 1,400 miles. The signals were barely audible, and not to be compared in intensity with the 9 p. m. (Central time) time signals. The signals of these stations have always been received here stronger as it became later in the evening. The aerial at this station is, however, not high enough to do long-distance receiving in daylight.

The writer does not consider that the evidence which has been presented in this and the preceding paper is in conflict with the theory of Dr. Eccles. On the other hand, it is in no wise to be explained by that theory, dealing as it does with refractions and reflections at relatively high altitudes. The author is inclined to accept the idea of a permanently ionized upper layer at great altitude; he is even willing to entertain the notion that the ionized middle region in daylight plays an important rôle in determining the generally large day absorption, but he considers that the evidence here submitted can only be accounted for by assuming a reflection at the cloud level brought about by a more or less abrupt alteration in the velocity of the wave above and below this level. It is not the clouds themselves that reflect, as good transmission between here and the Lake district has often been observed on very clear nights provided that the day has been cloudy. It is rather caused by an electrical discontinuity which persists after the clouds which caused it have perhaps long disappeared. It is difficult to believe that the probable degree of ionization by sunlight at the cloud level could be sufficient to be of influence, but so far no other more plausible suggestion has occurred to the writer. If this ionization is appreciable, then the clouds would in daylight produce a discontinuity layer which might persist for some hours after sunset. By the time this discontinuity fades away the ionization in the whole intermediate region of the atmosphere will be reduced so that waves may reach the permanently ionized upper layer and be reflected by it with little absorption. Thus good transmission will continue until the morning twilight. It naturally follows that general cloudiness would be beneficial in daylight. As far as observations taken at this station go, they fully agree with this. Unfortunately the day range of this station for reception of signals is not sufficiently great to settle this point definitely. The fact that cloudiness at the sender (where the radiant energy would without reflection be highly divergent) is more beneficial than at the receiver, seems to lend support to this theory. The theory leaves us without any adequate explanation of the day absorption which Austin has shown to be very regular in oversea transmission at least. We must therefore either assume that the daytime ionization under the cloud level averages much larger than is generally assumed, or that the radiation is divided as follows:

1. A portion reflected from the cloud level, and passing from sender to receiver as between two approximately parallel surfaces, and hence not following the inverse square law of divergence, and not heavily absorbed, since it travels in a feebly ionized medium.

2. A portion entering the middle ionized region and refracted back toward the earth according to the theory of Dr. Eccles. This portion would be absorbed during the day, but very feebly absorbed at night.

3. A portion passing through the middle region and partially reflected at the upper permanently ionized layer. This would be heavily absorbed during the day and feebly absorbed at night.

4. A portion which passes out into space is lost.

It is likely that the second portion is of the most importance in the daytime, while the vagaries of long distance nocturnal transmission are due to combinations at the receiver of the first and third portions. Those rapid variations in the strength of signals (swinging) and the slower fluctuations (fading) so familiar to operators in long range work may well be due to interference effects between these two portions.

The rapidity with which these effects often occur strongly suggests the idea of a violent commotion in the lower levels in the wave path.

Accordingly, daylight transmission over a clear area would be carried on mainly by the second portion, the third portion being heavily absorbed. Daylight transmission over a cloudy area (especially where cloudy at sender and its vicinity) would be reinforced by the first portion.

Nocturnal transmission following clear days would be carried on by the second portion reinforced by the third, both portions being feebly absorbed. Nocturnal trans-

[4] Phil. trans., A, 1907.

mission following cloudiness would in general be carried on by all three portions, but the evidence here presented suggests that the first portion, added to the third, both feebly absorbed, is of great importance.

Since completing this paper the writer has read an interesting account by Nipher, in the Proceedings of the Saint Louis Academy of Sciences, 1913, of local magnetic storms whose origin he believes to have traced to the influence of clouds. He finds also a period of magnetic disturbances coinciding with the well-known twilight fluctuations in radiotransmission. Prof. Nipher suggests a variation in the ionization of the *lower* levels caused by variations in the sunlight as the nature of this influence. There seems to be an intimate connection between these phenomena and the variations in radiotransmission.

Number.	Station.	Longitude.	First Phase.			Second Phase.		
			Arrival.	Maximum.	Principal maximum.	Arrival.	Maximum.	Principal maximum.
		1	2	3	4	5	6	7
		West. ° ′	1912.			1912.		
1	Katmai	155 0	June 6, eruption					
2	Mount Wilson	119 10				June 21, haze; July 1, actinom	July 4	No
3	Washington	77 0	June 10, haze					Aug. 15
4	West Greenland	50 0	After June 15; Before June 21					
5	Iceland	21 52	June 16	Between June 17–July 1	No	July 1–26		
		East.						
6	Algiers	4 0	June 19, haze; June 28–30, actin	July 6	No	July 11	July 11–20	No
7	Heidelberg	8 42	June 20, twilight	July 8–11	No	July 19	July 20–25	No
8	Zurich	8 33	June 23, vapor veil	July 12				
9	Hamburg	10 0	June 23, twilight					
10	Denmark	10 0	June 23	July 11	Yes; end of July	July 21	July 22; July 28	July 11
11	Pavia	9 10	June 27	July 11	Sept. 15	Absent	Absent	Absent
12	Salo	10 31	June 27	June 27	July 22	July 22	July 23	June 27
13	Ischia	13 50	June 24	July 9–12	No	July 24	July 27	Yes
14	Innsbruck	11 25	June 23	July 6–12, or later	No	Absent	Absent	Absent
15	Potsdam	13 0	June 24–27	July 10–15	Yes; like late summer	July 26	July 26; Aug. 1	Like July 10
16	Triest	13 50	June 24	July 13	Yes	July 28 (?)	(?)	No
17	Donnersberg	13 50	June 28	July 12–16	No	Indefinite (?)	Aug. 5 (?)	No
18	Tetschen	14 15	June 23	July 11–15	Yes	Absent	Absent	Absent
19	Fiume	14 25	June 28	July 15	No	July 24	July 24	Yes
20	Vienna	16 25	June 25–29	July 12–18	Yes; Aug. 1	July 28	July 28–Aug. 1	Yes; July
21	Häfringe	17 19	June 29	July 21	Yes	Absent		
22	Warsaw	21 01	June 26	July 26, after gaps	Yes; Aug. 22–Oct. 1	Aug. 2	Aug. 2–22	July 26–Oct. 1
23	Przegaliny	22 48	June 22 (?)	July 26	Yes	Absent	Absent	Absent
24	Sophia	23 15	June 26					
25	Athens	23 43	June 17	Increasing to Aug. 5	Oct. 1	Aug. 5	Aug. 5	Oct. 1
26	Egypt	31 0	June 28	July 3	No	Aug. 8	Aug. 8	Sept. 9

MAURER & DORNO ON THE PROGRESS AND GEOGRAPHICAL DISTRIBUTION OF THE ATMOSPHERIC-OPTICAL DISTURBANCE OF 1912-13.[1]

In January, 1913, Prof. J. Maurer of Zurich sent out, in his capacity as chairman of the Solar Radiation Commission of the International Meteorological Committee, a circular letter[2] requesting the meteorological institutes and bureaus of the world to compile and send to his commission complete details of observations that would help the study of the great atmospheric opacity which appeared over the Northern Hemisphere in 1912. A large amount of material was received in response to that request, and was placed in the hands of Maurer (Zurich) and C. Dorno (Davos) for discussion. The following paragraphs attempt to summarize the results as presented by the two authors in the paper first cited.

MATERIAL.

The first step in the discussion was to collect the records of the Campbell-Stokes sunshine recorders for those days of 1912 which yielded well-defined traces. These were compared with the records for the same localities on corresponding days of average or normal years; the best years immediately preceding 1912 were chosen as these standards of comparison. Of course there had been considerable variations in judgment of what constituted the beginning of the daily record-trace, in exposures and in instrumental peculiarities among so many contributing institutions. Particular difficulty arose in endeavoring to estimate the effects of low-lying haze and fog upon the Italian records. Eventually, however, the comparisons yielded a quantity of differences in the times of beginning of each day's record for 1912 as compared with the corresponding data for average years. These differences were then carefully reworked graphically by Dorno.

Then the actinometric and polarization observations were gone over in an equally careful, critical manner. The actinometer records were studied by comparing the daily maxima throughout 1912 with the average maxima for corresponding days and the resulting differences were plotted. In the polarization records the maximum and the minimum values of the antisolar distance of Arago's Point for 1912 were similarly compared with the average values for normal years. Finally all manuscripts and published notes on the sky were carefully compared with the plotted curves; the curves obtained from the sunshine recorders were supplemented by those from the photo-recording station at Tetschen and by the curves from practically all the actinometric and polarimetric observatories of the world. In all 36 such curves were prepared and studied; selections from them are reproduced as figure 1 of the article noticed, but must be omitted here.

[1] Summarized from: *Maurer, J., & Dorno, C.* Über den Verlauf und die geographische Verbreitung der atmosphärisch-optischen Störung, 1912-13. Met. Ztschr., Braunschweig, Feb. 1914, 31. Jhrg, pp. 49-62.
[2] See Meteorologische Zeitschrift, Braunschweig, Februar, 1913, 30. Jhrg, p. 92.